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INTRODUCTION TO EXTERNAL PLANT

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1. INTRODUCTION.

1.1 Each subscribers' telephone must be provided with a means of connection to its local exchange so that connection can be established between it and any telephone in the area. Also, each telephone exchange must have provision for connection to other exchanges in local, interstate and overseas localities.

While many of these connections, particularly those over long distances, are made by radio systems, many others, including all local connections are made by means of physical lines. These lines are mainly copper wires, either in underground cables or attached to poles on aerial routes.

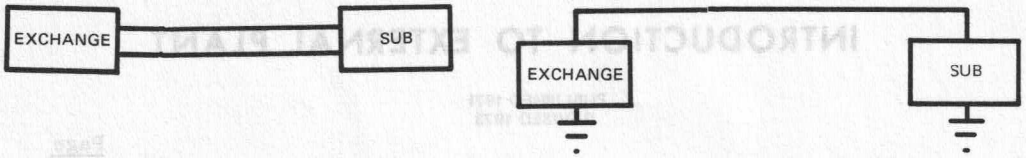
Physical lines and all associated plant external to telephone exchanges and subscribers premises are referred to as "external plant".

1.2 It is important to note that in addition to providing telephone services, many lines are used for other purposes such as connection of telegraph machines to switching centres, transmission of data, and relaying of radio and television programmes from one point to another.

1.3 This paper describes the functions of telephone lines, and the types of construction used. It also contains a brief description of the main items used in the construction of telephone lines.

2. TYPES OF LINES.

2.1 A telephone line generally consists of two wires, and this is called a "metallic" or "two-wire" line. When the earth (or the lead sheath of an underground cable, which is connected to earth) is used instead of one of the wires, the circuit is called an "earth-return" or "single-wire" line. (Fig. 1).



(a) Two wire line. (b) Single wire line.

FIG. 1. TYPES OF LINE.

Earth return circuits may be used for telegraph, switching or signalling circuits, but are rarely used for telephone circuits, because they provide a noisy, inferior type of service.

2.2 For identification purposes the two wires (conductors) of a metallic circuit are designated in various ways, such as:

- A side and B side.
- Line 1 and Line 2.
- Tip and ring.
- Positive (+) and negative (-).

In external plant, the terms A side and B side are generally used.

2.3 **FUNCTIONS OF TELEPHONE LINES.** To enable a subscriber's telephone to be connected to the local exchange and subsequently to another subscriber's service three functional types of line are provided. These are:

- SUBSCRIBERS LINES. These are the lines that connect subscriber's telephones to the local exchange.
- JUNCTION LINES. These lines connect two exchanges in the same or adjoining charging zones.
- TRUNK LINES. These lines connect two exchanges which are not in the same or adjoining charging zones. They are normally longer lines than junction lines.

Combinations of these lines may be used to set up a telephone connection between two subscribers. Fig. 2 shows the relative position in the overall telephone network of each type of line.

3. SUBSCRIBERS LINES.

3.1 To allow a large number of lines to be accommodated in a small space, telephone lines normally leave the exchange in underground cables; the size of the cables depends on the number of lines involved and the foreseeable future development of the area. The only exceptions to this method are isolated cases where very small post offices have, for example, one trunk line and one subscriber's line connected.

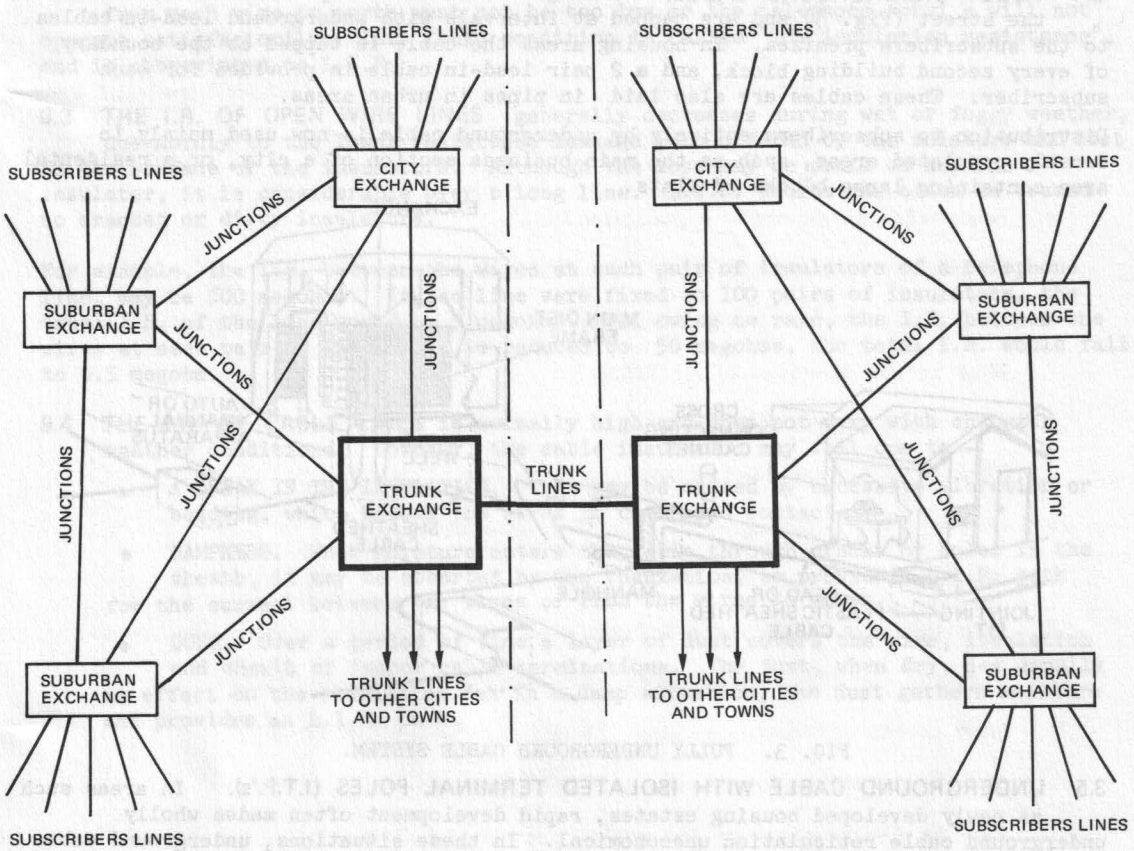


FIG. 2. THE TELEPHONE NETWORK.

3.2 Cables are installed in conduits or pipes laid between manholes and jointing pits which accommodate the cable joints. Conduits, which are pipes larger than 50 mm internal diameter, and manholes which are larger than jointing pits and enable workmen to enter them, are usually provided where one or a number of large size cables are installed along a street. At the manholes and jointing pits, smaller cables are tapped off as necessary to serve adjoining areas or streets.

3.3 Where the exchange-connected large cables taper into street feeds, and for the actual lead-in to the subscriber's premises there is a choice of the following systems:

- Fully underground cable.
- Underground cable with isolated terminal poles (I.T.P.'s).
- Aerial cable with I.T.P.'s.
- Open wire aerial.

3.4 FULLY UNDERGROUND CABLE. Underground cables are provided on both sides of the street (Fig. 3) and are tapped at intervals with underground lead-in cables to the subscribers premises. In housing areas the cable is tapped at the boundary of every second building block, and a 2 pair lead-in cable is provided for each subscriber. These cables are also laid in pipes in urban areas.

Distribution to subscribers entirely by underground cable is now used mainly in densely populated areas, such as the main business section of a city, or a residental area containing large blocks of flats.

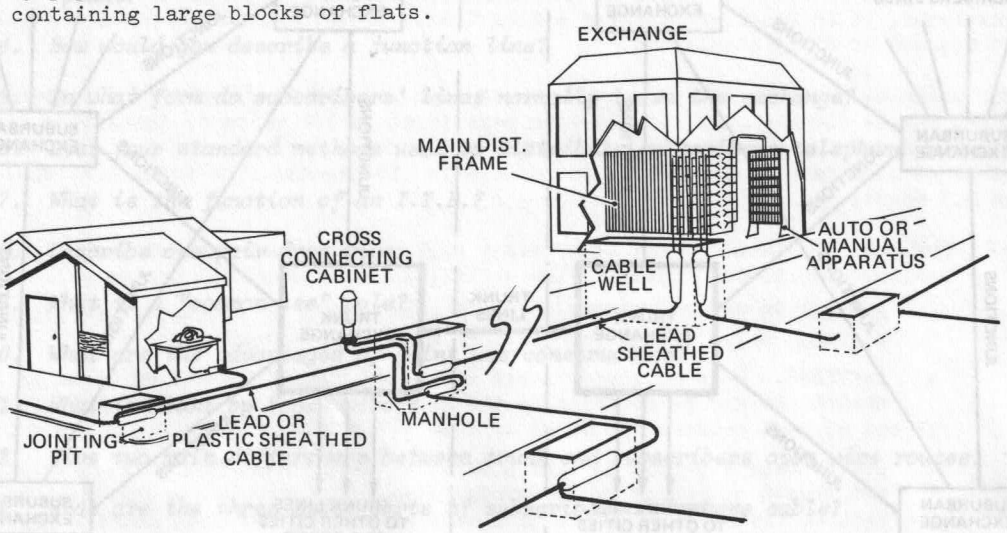


FIG. 3. FULLY UNDERGROUND CABLE SYSTEM.

3.5 UNDERGROUND CABLE WITH ISOLATED TERMINAL POLES (I.T.P.'s). In areas such as newly developed housing estates, rapid development often mades wholly underground cable reticulation uneconomical. In these situations, underground cable is laid on one side of the street only, and is tapped at regular intervals with small size cables which are taken from precast jointing pits and are connected to pole-mounted cable terminal boxes. The small cable is enclosed in metal or plastic pipe attached to the pole and is referred to as a 'riser' cable.

Poles used for this method of distribution are called "isolated terminal poles" "(I.T.P.'s)" and are usually located so that from four to eight subscribers can be fed from each I.T.P. This number includes subscribers on both sides of the street.

The aerial wire which connects subscribers to the I.T.P. is called "one pair drop wire" and consists of two conductors and supporting wire (bearer wire) enclosed in a plastic covering. It is usually erected from the I.T.P. to the subscribers premises in a single span but, if insufficient road clearance is available, a power pole may be used to provide intermediate support for the drop wire. This pole is then known as a "Common Use" pole and all attachments must conform to the "Code of Practice" agreed upon for the attachment of telecom wires to a power pole for the purpose of crossing the power wires carried by the pole. (This agreement is reciprocal to cover power wires attached to a P.M.G. pole for the purpose of crossing the telecom wire, see Fig. 7).

The bearer wire is attached by a special fitting to the subscribers premises and, in most instances the portion containing the conductors (bearer wire removed) is taken to the telephone location.

Fig. 4 shows a typical installation where underground cable, P.M.G. poles as I.T.P.'s, and common use power poles are used.

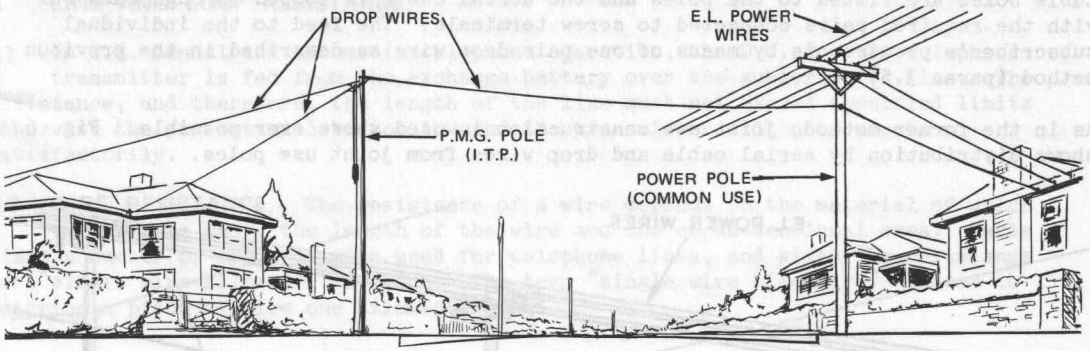


FIG. 4. UNDERGROUND CABLE WITH I.T.P.'s (P.M.G. POLES).

JOINT USE CONSTRUCTION. Where possible, poles belonging to the power authority (or, in some areas, jointly owned by P.M.G. and power authority) are used to support the riser cable, cable terminal box and drop wire attachments. This is referred to as "joint use construction" and has many benefits. For example:

- It is more economical than using separate poles for power and telephone distribution.
- It confines power and telephone distribution to one side of the street thus improving the general appearance of the locality.

Fig. 5 shows a typical example of joint use construction, with underground cable and I.T.P.'s.

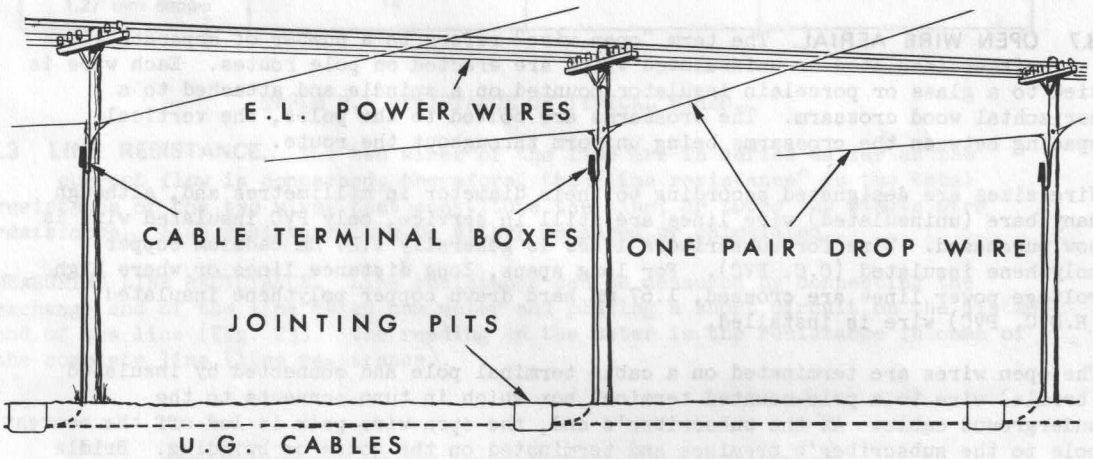


FIG. 5. UNDERGROUND CABLE WITH I.T.P.'s (JOINT USE CONSTRUCTION).

3.6 AERIAL CABLE WITH I.T.P.'s. In areas where it is uneconomical to lay underground cable due to local conditions, I.T.P.'s may be fed by plastic aerial cable. This cable, which usually incorporates a bearer wire is connected to the underground cable in a manhole or jointing pit adjacent to the first pole on the route, from where it is suspended between I.T.P.'s in the streets to be served. The pole spacing is similar to that used where underground cable feeds the I.T.P.'s.

Cable boxes are fitted to the poles and the aerial cable is looped through each box with the required pairs connected to screw terminals. The feed to the individual subscriber's premises is by means of one pair drop wire as described in the previous method (para. 3.5).

As in the former method, joint use construction is used where ever possible. Fig. 6 shows distribution by aerial cable and drop wires from joint use poles.

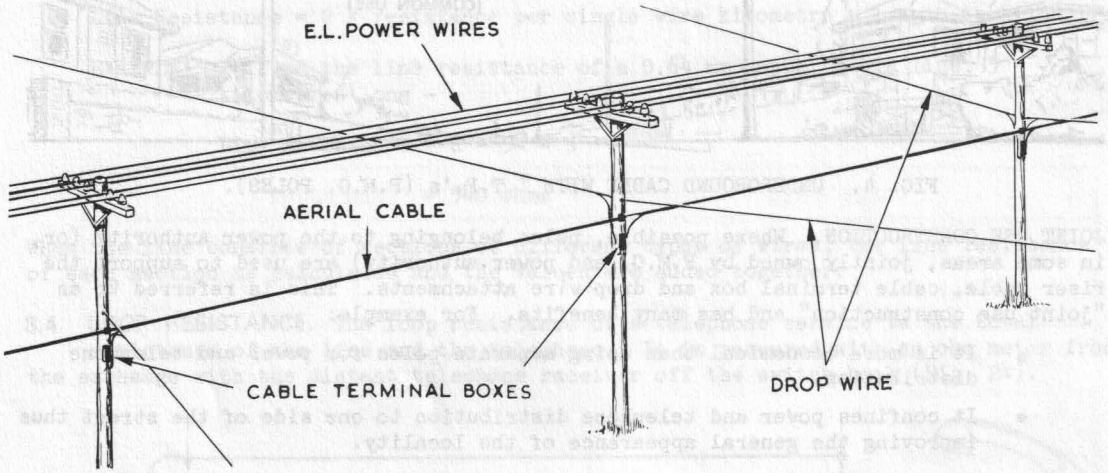


FIG. 6. AERIAL CABLE WITH I.T.P.'s (JOINT USE CONSTRUCTION).

3.7 OPEN WIRE AERIAL. The term "open wire" refers to a number of separate wires either insulated or uninsulated which are erected on pole routes. Each wire is tied to a glass or porcelain insulator mounted on a spindle and attached to a horizontal wood crossarm. The crossarms are bolted to the poles, the vertical spacing between the crossarms being uniform throughout the route.

Wire sizes are designated according to their diameter in millimetres and, although many bare (uninsulated) wire lines are still in service, only PVC insulated wire is now purchased. Wire for subscribers lines is generally 1.27 mm cadmium copper polythene insulated (C.C. PVC). For long spans, long distance lines or where high voltage power lines are crossed, 1.67 mm hard drawn copper polythene insulated (H.D.C. PVC) wire is installed.

The open wires are terminated on a cable terminal pole and connected by insulated (bridle) wire to a pole-mounted terminal box which in turn connects to the underground cable. At the subscriber's end, the open wire pair is led off the nearest pole to the subscriber's premises and terminated on the house or building. Bridle wire is used to connect the open wire to a terminal block or protective device from which the internal wiring leads away to the internal equipment (telephone etc.) In some cases the bridle wire is run directly to the telephone.

This type of construction is now used mainly in country areas where the subscribers are widely distributed over a large area. It was at one time the major method of subscribers' distribution but has been generally superseded by methods described previously, owing to the greatly increased density of subscribers services. Fig. 7 shows a small section of subscriber's open wire aerial construction. Note the P.M.G. pole used for "Common Use" construction.

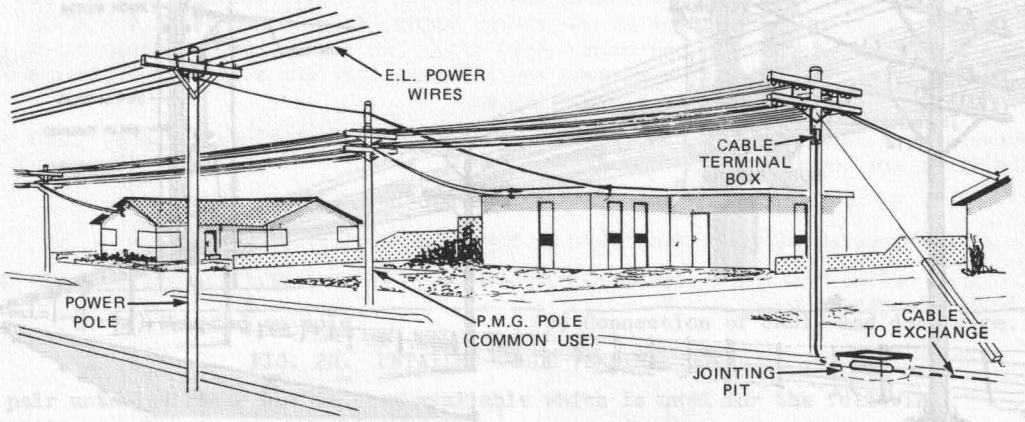


FIG. 7. OPEN WIRE AERIAL CONSTRUCTION.

4. TRUNK AND JUNCTION LINES.

4.1 TRUNK LINES. Physical lines for the provision of trunk circuits are open wire aerial, underground pair cable and coaxial cable.

Open wire routes were used almost exclusively up to the 1950's. During the latter part of this period a large number of pair cable carrier systems were installed between large cities up to about 240 kilometres apart.

In 1959 installation of the first coaxial cable system was commenced, which was followed by numerous coaxial cable installations to help provide the large number of trunk channels made necessary by the increasing demand.

4.2 JUNCTION LINES. These lines are usually accommodated in subscribers' type underground cable, and in some cases, in country areas on open wire aerial routes.

4.3 Descriptions of cable used on trunk and junction lines are in the following Sections of this paper.

4.4 OPEN WIRE TRUNK LINES. This form of construction is basically similar to that used on open wire subscribers lines. The main difference between the two is that in trunk construction the wires are a larger diameter (usually 2.84 mm H.D.C.), the crossarms are usually longer (2.8 metres) and the vertical spacing between the crossarms varies from 355 mm to 1060 mm. The greater distance between the crossarms or main routes means that the poles are generally longer to provide the necessary clearance between the wires and roads, railway lines etc. Trunk open wire routes often carry open wire subscribers lines on the lower crossarms. Fig. 8 shows portion of a typical trunk route.

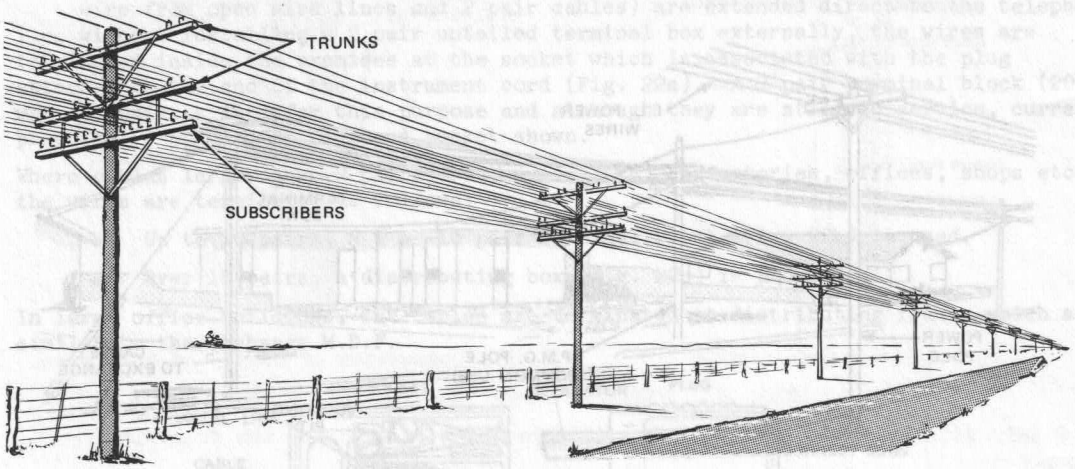


FIG. 8. OPEN WIRE TRUNK ROUTE.

Open wire trunk lines are usually connected to the trunk exchange (terminal), or to intermediate buildings housing equipment, by an underground cable which runs from the terminal pole to the equipment in the building.

This cable is referred to as a trunk entrance cable and is used where the direct connection of the open wires to the building is not physically or eletrically practicable. Fig. 9 shows a simple trunk entrance arrangement at a terminal station. The trunk terminal pole carries a cable terminal box and where necessary, additional equipment such as protectors, filters, etc. in weather-proof boxes.

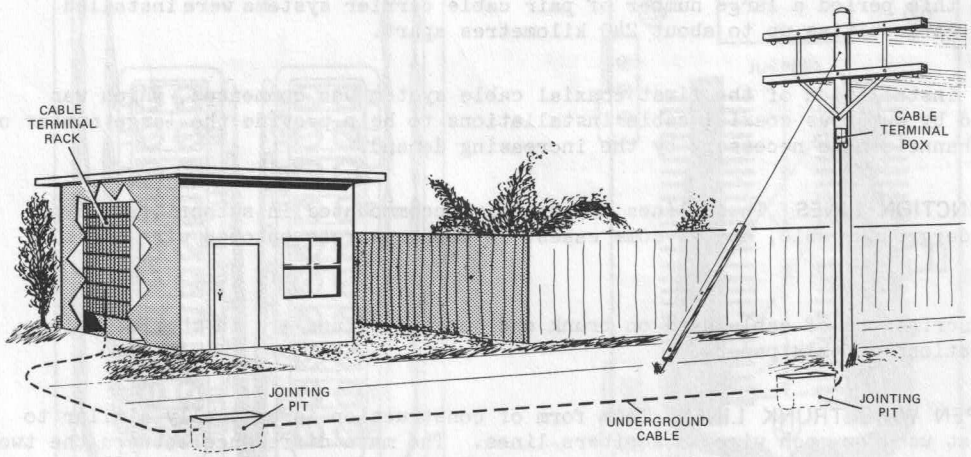


FIG. 9. TRUNK ENTRANCE ARRANGEMENTS.

5. SUBSCRIBERS CABLE TYPES.

5.1 Cable used for subscribers' lines consists of two or more pairs of insulated wires enclosed in a sheath. One pair cable, which is obsolete except as a long distance rural subscribers cable, and has been superseded by two pair cable, is still in service in many localities.

Because of the variety of conditions that have to be considered, many types and sizes of cable are used in a subscribers network.

5.2 All cables, regardless of type and size, have three basic parts:

- The wire (often referred to as "conductor").
- The insulating material.
- The sheath.

5.3 **WIRE.** Soft copper wire is generally used; trial installations of aluminium wires have been made to evaluate the suitability of aluminium as a replacement for copper. Cable wire sizes are also designated according to their diameter and the most common sizes of copper wire used in subscribers cables are:

0.32 mm, 0.40 mm and 0.64 mm.

Some long distance subscribers cables in country areas have 0.90 mm wires. Many cables with 0.51 mm or 0.71 mm wires are still in service but these sizes are not now purchased.

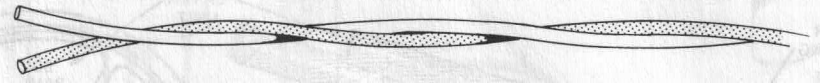
5.4 **INSULATING MATERIAL.** This is used to insulate the wires from each other and the sheath. Various materials are used including paper (woodpulp and manila) and plastic (polythene and polyvinyl chloride).

Wire insulation is either fully coloured or has coloured markings to provide a means of identification.

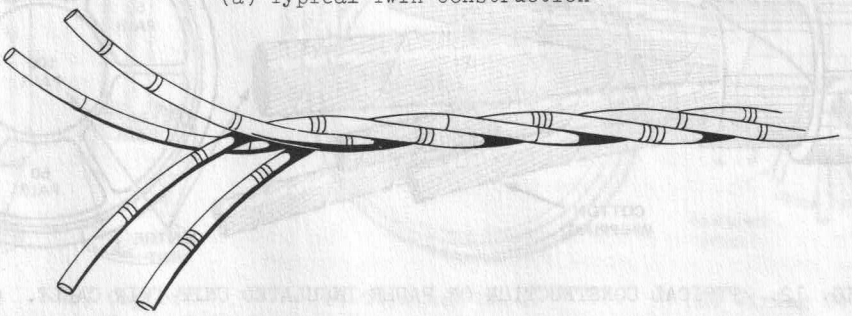
5.5 **SHEATH.** This is the outer covering of the cable which protects the wires from damage or moisture. The sheath material varies depending on the requirements for the particular application of the cable. Types of sheath available are lead, polythene and moisture barrier. Moisture barrier sheathing consists of a polythene sheath bonded to an aluminium foil which is applied over the paper or polythene insulated wires comprising the cable.

Additional protection is provided in special cases where there is danger of damage from mechanical implements, corrosion, termites etc. Types of sheath protection include polythene and nylon jacketing, steel tape and wire armouring.

5.6 **MAKE-UP OF SUBSCRIBERS' CABLE.** The insulated wires are twisted in groups of two to form pairs (TWIN CABLE) or in groups of four to form quads (QUAD CABLE) as shown in Fig. 10. The length of twist varies so that no two adjacent pairs or quads have the same length of twist. This reduces induction or "crosstalk" between pairs.



(a) Typical Twin Construction



(b) Typical Quad Construction

FIG. 10. CABLE WIRES.

PAPER INSULATED QUAD cable (Fig. 11) is made up of a centre containing one or more quads around which is spirally wound an assembly of quads to form the first layer of the cable. A second layer of quads is then spirally wound around the first layer, and so on for the remaining layers until the required cable size is reached. This operation is called 'stranding' and the direction of stranding is alternated (i.e. clockwise then anti-clockwise) in successive layers to asist in further reducing crosstalk.

The centre and each layer is provided with one quad with special markings referred to as the MARKER which is the first quad in the centre or layer.

On completion of stranding, the cable core is bound with paper and then has the sheathing applied by a method known as extrusion.

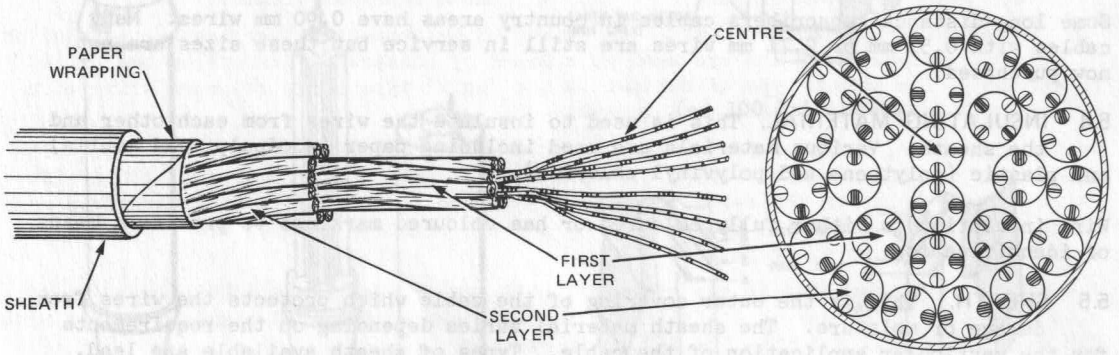


FIG. 11. TYPICAL CONSTRUCTION PAPER INSULATED QUAD CABLE.

PAPER INSULATED TWIN cable is in its intial stages constructed as described for quad cable with two major variations. Firstly, pairs of wires not quads are used and secondly, stranding of the layers does not alternate in successive layers.

Twin cable also involves an additional operation known as UNIT construction in which a number of cable cores called UNITS are grouped together to form a cable of the required size before the sheath is fitted.

These units consists of 10, 25, 50 or 100 pairs and combinations of various sizes of units may be assembled to form the cable as shown in Fig. 12. Identification markings are provided to indicate the MARKER UNIT in each layer of units (and the centre, if it contains more than one unit).

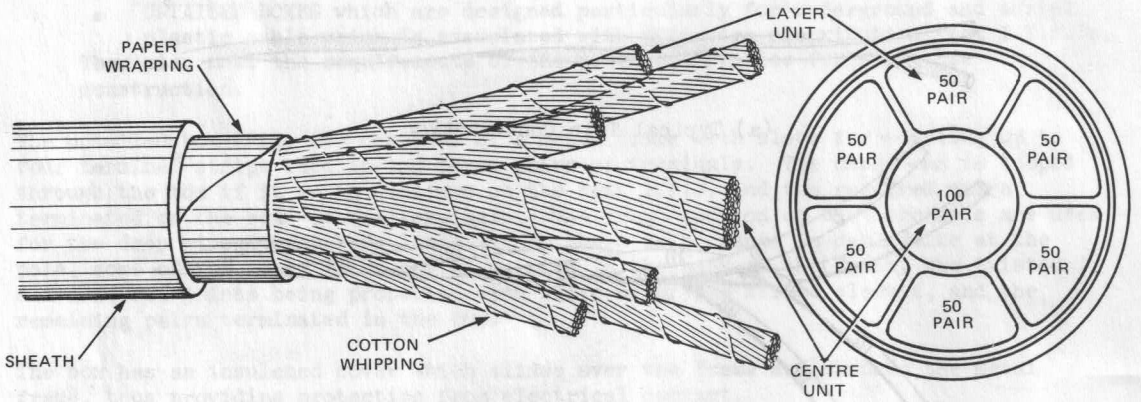


FIG. 12. TYPICAL CONSTRUCTION OF PAPER INSULATED UNIT TWIN CABLE.

POLYTHENE INSULATED cable employs either UNIT TWIN or UNIT QUAD construction. Ten pairs (or five quads) of polythene insulated wires are bunched together to form 10 pair units which are then grouped together to form the completed core or, in the case of large size cables, to form 50 or 100 pair units which in turn are assembled to form the ultimate cable size. The completed core is wrapped with an insulating material (usually paper) and then sheathed with extruded polythene.

Within a unit, the insulation on the wires is coloured in accordance with the standard colour code applicable (i.e for either twin or quad construction) and which is repeated in each unit of the cable. To identify the various units, polythene binder tapes, coloured in accordance with a standard colour code, are applied over the units.

5.7 Cable described in para. 5.6 is generally referred to as "pair cable" to avoid confusion with other types of cable such as coaxial. Other terms sometimes used are "balanced pair", "multi-conductor" and "layer" cable.

5.8 ROTATION COUNTING IN PAPER INSULATED CABLES. The numbering of the pairs or quads commences from the "marker" in the centre of the cable and continues in rotation throughout the layers to the last pair or quad in the outside layer.

In all States, except South Australia and Western Australia, the direction of rotation is clockwise looking towards the exchange as shown in Fig. 13.

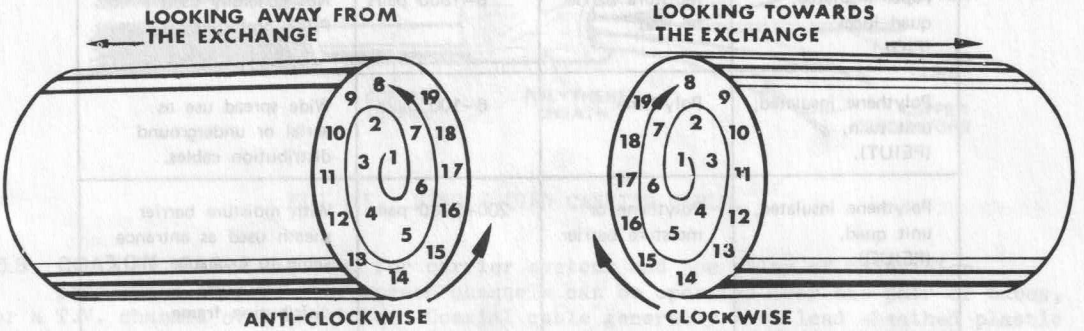


FIG. 13. ROTATION COUNTING OF PAIRS AND QUADS (N.S.W., VIC., QLD., TAS.).

In South Australia and Western Australia, the direction is reversed and is shown in Fig. 14.

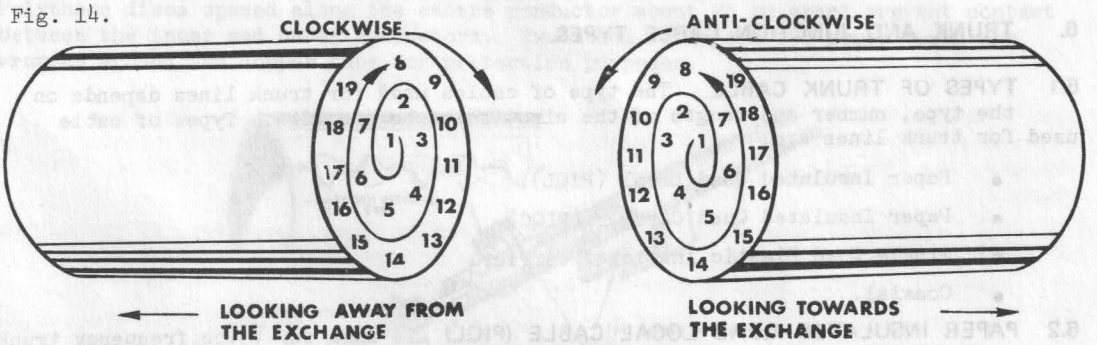


FIG. 14. ROTATION COUNTING OF PAIRS AND QUADS (S.A. AND W.A.)

In unit type cable, the same procedure applies not only to the pairs within each unit but also to the unit sequence in the cable.

5.9 NUMBERING IN POLYTHENE INSULATED CABLES. As these cables have a distinctive colour code, the pairs or quads are always numbered in sequence according to the colour code for that particular type of cable.

5.10 CABLE TYPES IN GENERAL USE. Table 1 shows the types of subscribers cable in general use at the present time (1973).

In addition to those shown, special types of cables are used, for example:

- LEAD-IN CABLES - which are usually 2 pair cables (a 1 pair 1.27 mm cable is used in the country for long runs) are available with paper, polythene and P.V.C. insulated wires enclosed under various sheaths.
- TAIL CABLES - for the connection of paper insulated lead sheathed cables to polythene insulated and sheathed cables. Provided in various sizes with polythene insulation and a lead sheath.

TYPE OF CORE	TYPE OF SHEATHING	CABLE SIZE RANGE	REMARKS
Paper insulated, unit twin. (PIUT)	Moisture barrier or lead.	6–4200 pairs	Mostly the larger size cables with moisture barrier sheaths are used.
Paper insulated, quad local. (PIQL)	Moisture barrier or lead	6–1800 pairs	Not generally used – PIUT preferred.
Polythene insulated, unit twin. (PEIUT).	Polythene.	6–100 pairs	Wide spread use as aerial or underground distribution cables.
Polythene insulated, unit quad. (PEIUQ).	Polythene or moisture barrier	200–2700 pairs	With moisture barrier sheath used as entrance cable to exchange M.D.F. and subscribers distribution frame.

TABLE 1. SUBSCRIBERS CABLE TYPES AND USES.

6. TRUNK AND JUNCTION CABLE TYPES.

6.1 TYPES OF TRUNK CABLE. The type of cables used for trunk lines depends on the type, number and length of the circuits to be provided. Types of cable used for trunk lines are:

- Paper Insulated Quad Local (PIQL).
- Paper Insulated Quad Carrier (PIQC).
- Single Quad Plastic Insulated Carrier.
- Coaxial.

6.2 PAPER INSULATED QUAD LOCAL CABLE (PIQL) is used for voice frequency trunk circuits on minor routes over distances of up to about 32 kilometres.

The cable may be used as a combined subscribers' and trunk cable and would have 0.64 mm or 0.90 mm conductors. Constructional details of PIQL cable are covered in Section 5.

6.3 PAPER INSULATED QUAD CARRIER CABLE (PIQC) is similar in construction to PIQL but is manufactured to closer tolerances to give more efficient transmission performance than PIQL. It has 0.90 mm or 1.27 mm conductors which are used as bearers for 12 channel carrier systems. Normally these cables are used where the ultimate requirement is 240 channels over distance up to 120 kilometres. PIQC cables are made in 14 pair and 24 pair sizes and are lead sheathed. The sheath may be protected with similar materials to subscribers' lead sheathed cables.

6.4 SINGLE QUAD PLASTIC INSULATED CARRIER CABLE (Fig. 15) is used to provide a large number of channels (up to 240) on two cables. The cables are known as the "go" and "return" cables. It has four 1.27 mm conductors, insulated with polythene and quadded around a solid polythene core. The quad is whipped with a coloured tape, wrapped with terylene tape and covered with a heavy polythene sheath. A copper tape is applied longitudinally over the sheath and the whole covered with a hard nylon jacket. Blue coloured whipping is used to denote "go" type cable and orange denotes "return" cable.

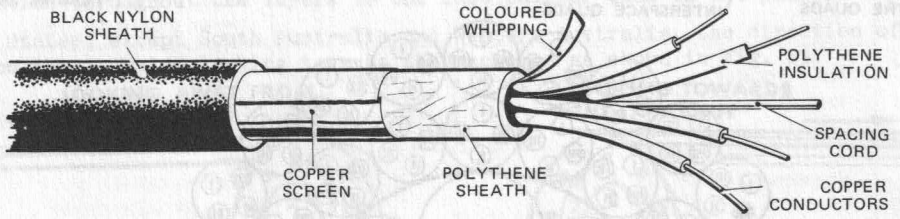


FIG. 15. SINGLE QUAD CARRIER CABLE.

6.5 COAXIAL CABLE is used for carrier systems and the relay of television programmes. Up to 2700 speech channels can be operated over one pair of tubes, or a T.V. channel over one tube. Coaxial cable generally is a lead sheathed plastic jacketed cable and contains up to 12 coaxial tubes together with paper insulated conductors. Each coaxial tube (Fig. 16) consists of a central copper conductor (2.6 mm diameter) enclosed in a copper tube which forms the outer conductor. Polythene discs spaced along the centre conductor about 25 mm apart prevent contact between the inner and outer conductors. Two steel tapes and two paper tapes are wrapped around the copper tube for protection purposes.

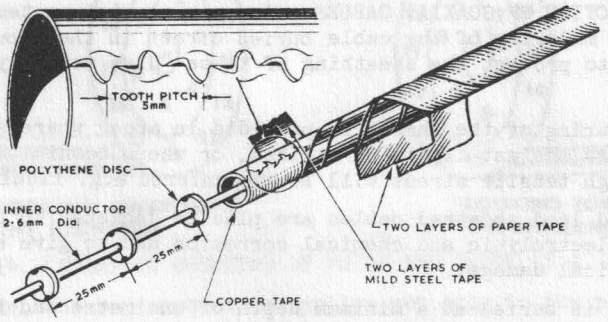


FIG. 16. COAXIAL TUBE DETAILS.

The tubes are laid-up around a centre core consisting of paper insulated 0.90 mm twin or quad wires. One 0.90 mm quad is placed in each of the interstices (gaps) formed between the tubes; these quads are called "interspace" quads. The assembly is then wrapped with paper and, if required, one or more layers of 0.64 mm or 0.90 mm paper insulated quads are laid-up around the composite cable followed by the final paper wrappings. The paper insulated wires are used for trunk lines to wayside stations along the coaxial cable route, also for alarm and control circuits.Fig. 17 shows the make-up of a typical 4-tube coaxial cable.

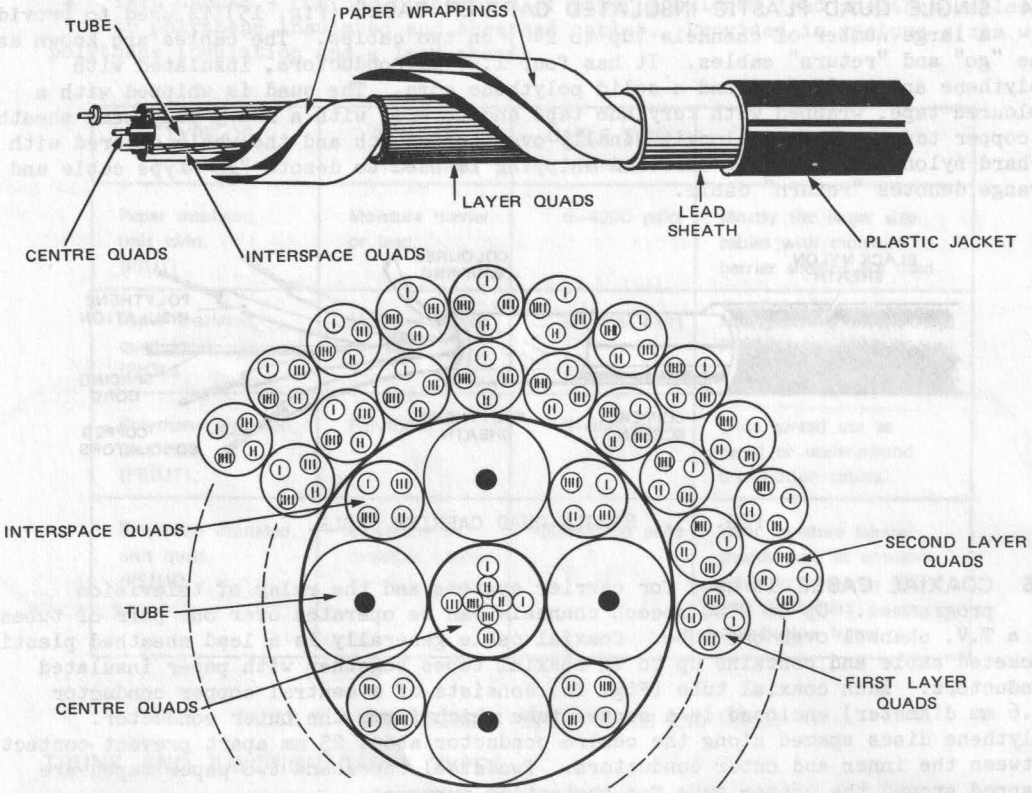


FIG. 17. TYPICAL 4-TUBE COAXIAL CABLE.

SHEATHING AND PROTECTION OF COAXIAL CABLES. As most coaxial routes span long distances, with the majority of the cable buried direct in the ground, special measures are taken to protect the sheathing of these "high security" routes. For example:

- Wire armouring of the sheath is provided in areas where special protection is required against lightning strikes, or where conditions of heavy abrasion or high tensile stress will be encountered e.g. tidal estuaries.
- Unarmoured lead sheathed cables are plastic jacketed to provide protection against electrolytic and chemical corrosion and to give some protection against mechanical damage.
- The cable is buried at a minimum depth of one metre and the route is clearly marked with warning posts to reduce the risk of accidental damage due to excavating operations.

6.6 JUNCTION CABLE. Cable used for junction lines is usually PIQL as described in Section 5. To eliminate crosstalk that may occur due to the length of cable, a number of jointing patterns are used at predetermined joints.

7. CABLE TERMINAL UNITS.

7.1 All cable pairs for trunk, junction and subscribers lines originate at an exchange where they are terminated to a distribution frame. Similarly in most instances, cable pairs for trunk and junction lines are terminated in the exchange at the distant end of the cable. (One exception would be when the line changes from cable to aerial construction). However, the cable pairs for subscribers lines must be provided with terminal points at numerous locations along the route of the cable to cater for distribution to the individual subscribers. Subscribers cable pairs may be terminated at any of the following terminal units:

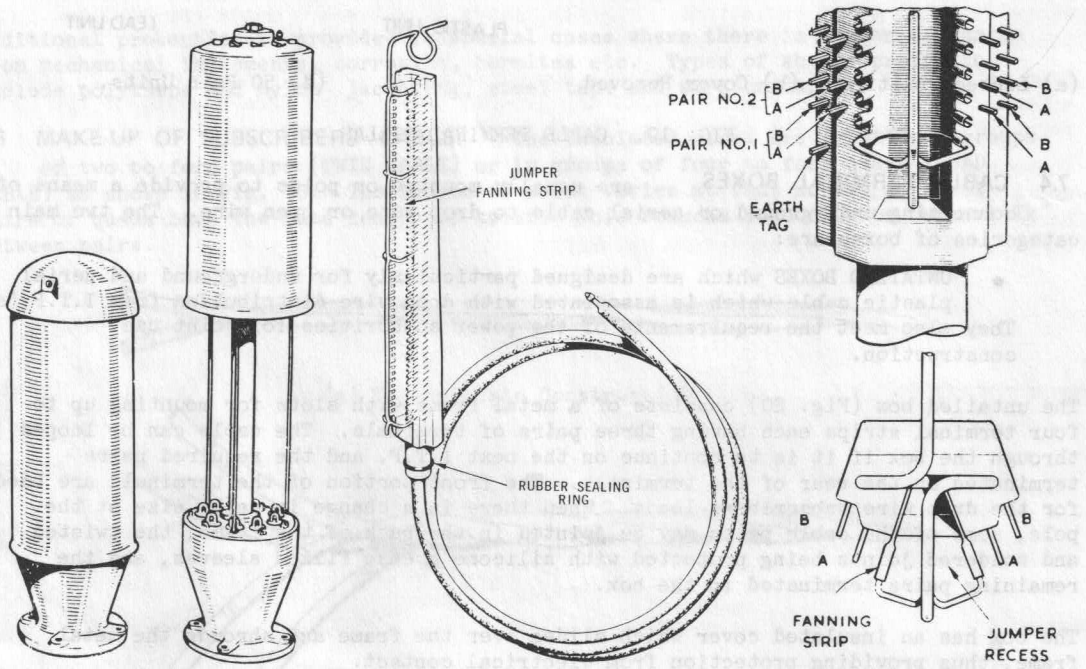
- Cross-connecting cabinets.
- Cable terminal boxes.
- Cable terminal pillars.
- Cable terminal blocks.

7.2 **CROSS-CONNECTING CABINETS** are installed in streets either against a fence or in the nature strip and are used as a means of connecting pairs from one cable to another. The modern type of cabinet is the "unit" type (Fig. 18) consisting of a cylindrical shaped base, cover and lockable cap.

Inside the cover, a number of terminal units are mounted vertically in the base, with the rubber sealing rings providing airtight seals. Each unit consists of 100 or 200 pairs of tags to which the cable tails are connected and sealed in an epoxy resin block. The cable tails are either lead or plastic sheathed to suit the street cable to which the unit is to be jointed.

The cabinets are supplied in two sizes suitable for 900 pairs and 1800 pairs; up to nine 100 pair units may be installed in the 900 pair cabinet and similarly up to nine 200 pair units will fit into the 1800 pair cabinet.

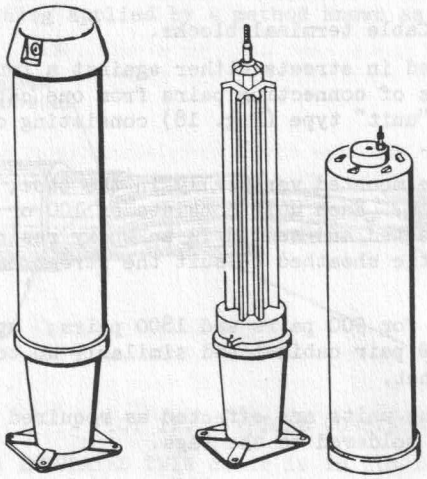
Cross-connections between the tags of the various units are effected as required by "jumpering" with insulated wires which are then soldered to the tags.



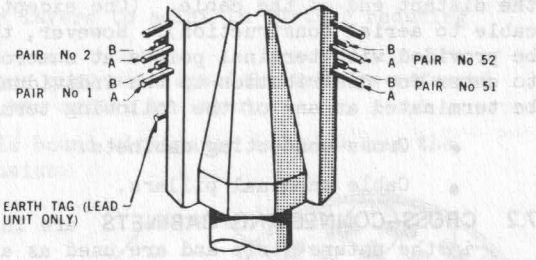
(a) Locked Position. (b) Cap off-Cover Raised. (c) Terminal Unit. (d) Wiring Details.

FIG. 18. CROSS-CONNECTING CABINET.

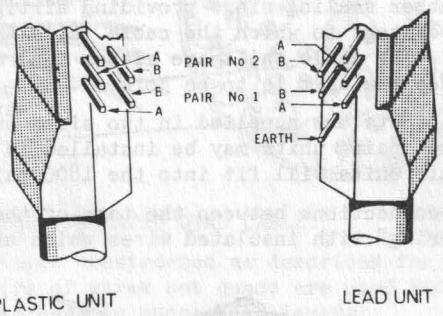
7.3 CABLE TERMINAL PILLARS are of similar construction to cabinets but are only available in one size, namely 300 pairs. The pillar (Fig. 19) accommodates up to two 100 pair and two 50 pair units, which are available with lead or plastic cable tails, and provides the same cross-connecting facilities between pairs of different cables as a cabinet but on a reduced scale.



(a) Locked Position (b) Cover Removed



(c) 100 Pair Units.



(d) 50 Pair Units.

FIG. 19. CABLE TERMINAL PILLAR.

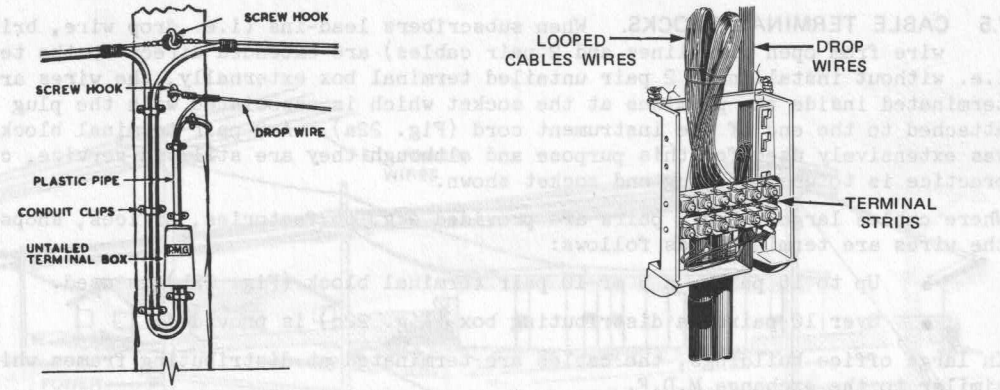
7.4 CABLE TERMINAL BOXES are usually mounted on poles to provide a means of connecting underground or aerial cable to drop wire or open wire. The two main categories of boxes are:

- UNTAILED BOXES which are designed particularly for underground and aerial plastic cable which is associated with drop wire distribution from I.T.P.'s. They also meet the requirements of the power authorities for joint use construction.

The untailed box (Fig. 20) consists of a metal frame with slots for mounting up to four terminal strips each having three pairs of terminals. The cable can be looped through the box if it is to continue on the next I.T.P. and the required pairs terminated on the rear of the terminals. The front portion of the terminals are used for the drop wire subscribers leads. When there is a change in cable size at the pole, some of the cable pairs may be jointed in the back of the frame, the twisted and soldered joints being protected with silicone grease filled sleeves, and the remaining pairs terminated in the box.

The box has an insulated cover which slides over the frame and shrouds the metal frame, thus providing protection from electrical contact.

Fig. 20 (a) shows an untailed cable box mounted on a pole and used in conjunction with integral bearer plastic aerial cable. Fig. 20 (b) shows the method of terminating cable pairs and drop wire in the box.



(a) Mounted on pole. (b) Connection of cable and drop wire.

FIG. 20. UNTAILED CABLE TERMINAL BOX.

A 2 pair untailed cable box is also available which is used for the following purposes:

(a) On poles, to connect one or two aerial lines to underground cables.

(b) At subscribers premises, where the aerial or cable lead-in cannot be extended to the telephone and it is therefore necessary to terminate the line outside the building to provide a junction between the outdoor and indoor wiring.

• TAILED BOXES are designed primarily for use on routes consisting of underground cable and open wire, but are seldom installed now due to the rapid decline of open wire construction. They are known as tailed boxes because the terminal assembly is supplied with the cable tail fitted.

These boxes are available in 2, 10 and 15 pairs sizes fitted with plastic cable tails for subscribers and minor trunk lines. For major trunk lines, a 24 pair box fitted with a P.I.Q.C. cable tail is provided. All sizes are available with arrester springs fitted so that arresters may be installed for protection from lightning if required.

Where a tailed box is to be used and protection is not required e.g. when only a short length of open wire construction is involved, a 10 pair unprotectable type cable box is provided.

A typical 15 pair protected box is shown in Fig. 21. It has a metal base for attachment to the pole, a box assembly containing the end of the cable tail connected to the terminals and moulded into an epoxy resin block, and a metal cover which slides over the assembled unit. The bridle wire is connected to the cable terminals and taken up the pole for connection to the open wire terminations.

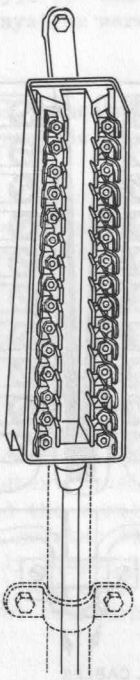


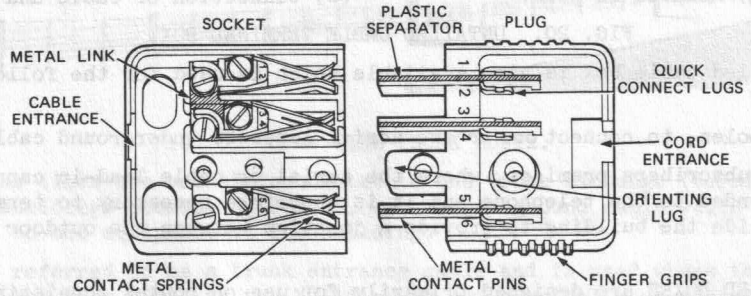
FIG. 21. 15 PAIR PROTECTED CABLE TERMINAL BOX.

7.5 CABLE TERMINAL BLOCKS. When subscribers lead-ins (i.e. drop wire, bridle wire from open wire lines and 2 pair cables) are extended direct to the telephone i.e. without installing a 2 pair untailed terminal box externally, the wires are terminated inside the premises at the socket which is associated with the plug attached to the end of the instrument cord (Fig. 22a). A 2 pair terminal block (20/4) was extensively used for this purpose and although they are still in service, current practice is to use the plug and socket shown.

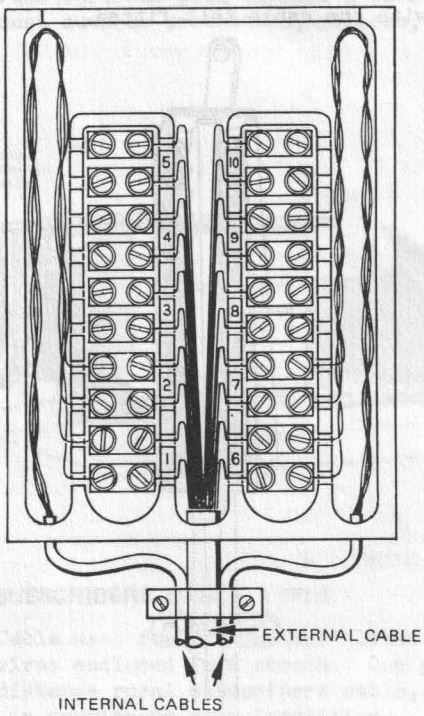
Where cables larger than 2 pairs are provided e.g. at factories, offices, shops etc. the wires are terminated as follows:

- Up to 10 pairs, a 5 or 10 pair terminal block (Fig. 22b) is used.
- Over 10 pairs, a distributing box (Fig. 22c) is provided.

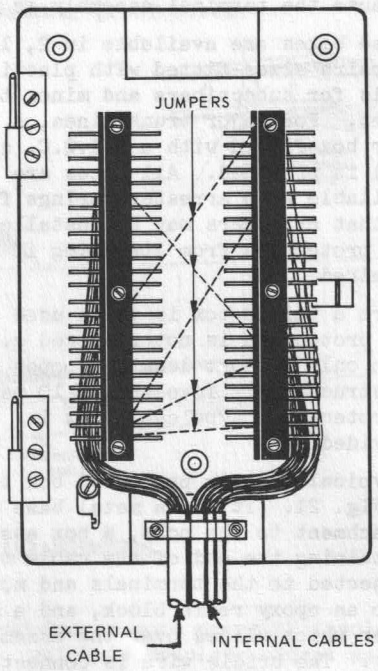
In large office buildings, the cables are terminated at distributing frames which are similar to the exchange M.D.F.



(a) Instrument Plug and Socket.



(b) 10 pair Cable Terminal Block.



(c) 50 pair Distributing Box.

FIG. 22. CABLE TERMINALS AT SUBSCRIBERS PREMISES.

8. LINE AND LOOP RESISTANCE.

8.1 In C.B. manual and automatic telephone operation, the D.C. for the telephone transmitter is fed from the exchange battery over the subscriber's line. The resistance, and therefore, the length of the line must not exceed specified limits otherwise the current will be too low and the transmitter will not operate satisfactorily.

8.2 WIRE RESISTANCE. The resistance of a wire depends on the material of which the wire is made, the length of the wire and the cross-sectional area. Table 2 lists a number of types of wire used for telephone lines, and gives the resistance per "single wire kilometre" of each. The term "single wire kilometre" is used to describe a piece of wire one kilometre long.

CABLE WIRES		OPEN WIRES	
SIZE AND TYPE OF WIRE	APPROX. RESISTANCE PER SINGLE WIRE KILOMETRE (ohms)	SIZE AND TYPE OF WIRE	APPROX. RESISTANCE PER SINGLE WIRE KILOMETRE (ohms)
0.32 mm copper	218	1.27 mm C.C.	16
0.40 mm copper	136	1.67 mm C.C.	9
0.51 mm copper	84	2.18 mm C.C.	5.6
0.64 mm copper	54	3.07 mm C.C.	2.8
0.71 mm copper	44	2.01 mm H.D.C.	5.5
0.90 mm copper	27	2.84 mm H.D.C.	2.7
1.27 mm copper	14		

TABLE 2. RESISTANCE OF TYPICAL WIRES.

8.3 LINE RESISTANCE. The two wires of the line are in series as far as the current flow is concerned, therefore, the "line resistance" is the total resistance of the two wires that constitute the line, *or twice the single wire resistance*. Line resistance can be either measured or calculated.

MEASURING LINE RESISTANCE. Line resistance can be measured by connecting the exchange end of the line to an ohm meter and placing a short circuit on the distant end of the line (Fig. 23). The reading on the meter is the resistance in ohms of the complete line (line resistance).

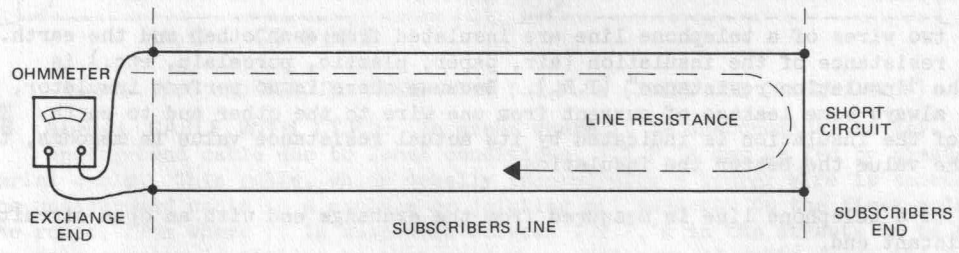


FIG. 23. MEASURING LINE RESISTANCE.

Line resistance plays an important part in the location of faults on telephone lines. For example if a line is short circuited between the exchange and the telephone or in the case of trunk lines, between exchanges, measurement of the line resistance enables the distance to the short circuit to be determined accurately.

CALCULATING LINE RESISTANCE. Line resistance can be calculated when the exact length of the line is known. The following formula is used:

Line Resistance = 2 × resistance per single wire kilometre × length in kilometres

EXAMPLE: To find the line resistance of a 0.64 mm copper cable line, 5 kilometres long -

Line Resistance = 2 × 54 × 5

= 540 ohms

When the line consists of sections of different types of wires, the line resistance of each section is calculated and the values are added together.

8.4 LOOP RESISTANCE. The loop resistance of a telephone service is the total resistance of the line and the telephone. It is measured with an ohm meter from the exchange with the distant telephone receiver off the switch hook (Fig. 24).

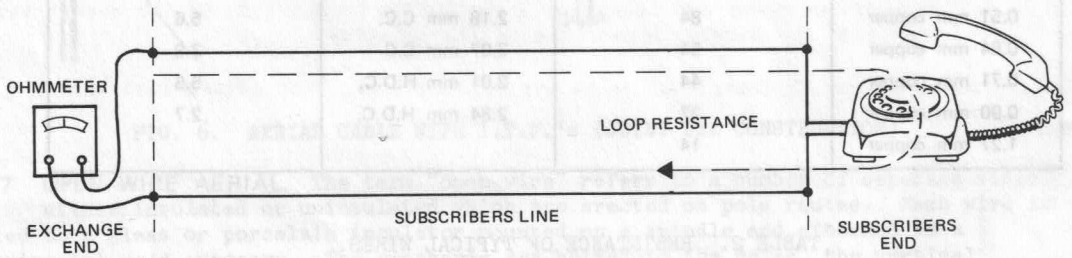


FIG. 24. MEASURING LOOP RESISTANCE.

When a new telephone service is installed the loop resistance is measured and recorded on the subscriber's master card which is kept at the exchange.

When a fault condition occurs on the service, a comparison of the resistance indicated by test and the loop resistance of the service may assist when diagnosing the fault.

9. INSULATION RESISTANCE.

9.1 The two wires of a telephone line are insulated from each other and the earth. The resistance of the insulation (air, paper, plastic, porcelain, etc.) is called the "insulation resistance" (I.R.). Because there is no perfect insulator, there is always some leakage of current from one wire to the other and to earth. The quality of the insulation is indicated by its actual resistance value in megohms, the higher the value the better the insulation.

The I.R. of a telephone line is measured from the exchange end with an open circuit at the distant end.

9.2 The longer the line, the lower the I.R. becomes. The I.R. between wires and from each wire to earth must not be too low or the telephone servi e will not operate satisfactorily. This fault condition is called "low insulation resistance", and is abbreviated to L.I.R.

9.3 **THE I.R. OF OPEN WIRE LINES** generally decreases during wet or foggy weather, due mainly to the lower resistance leakage path offered by the moisture and dust on the surface of the insulators. Although the loss may be small on any one insulator, it is considerable over a long line. L.I.R. faults can often be traced to cracked or dirty insulators.

For example, the I.R. between the wires at each pair of insulators of a telephone line, may be 500 megohms. If the line were fixed to 100 pairs of insulators, the total I.R. of the line would be 5 megohms. If, owing to rain, the I.R. between the wires at each pair of insulators is reduced to 50 megohms, the total I.R. would fall to 0.5 megohm.

9.4 **THE I.R. OF CABLE LINES** is normally high and does not vary with changing weather conditions. However, the cable insulation may fail due to -

- A BREAK IN THE INSULATION. This may be caused by excessive vibration or bending, which allows the wires to come into contact.
- DAMPNESS. When moisture enters the cable through cracks or holes in the sheath, it may be absorbed by the insulation, to provide a L.I.R. path for the current between the wires or from the wires to earth.
- DUST. Over a period of time a layer of dust covers the wire, insulation and sheath of indoor cable terminations. The dust, when dry, has usually no effect on the insulation but in a damp situation, the dust gathers moisture and provides an L.I.R. path.

10. TEST QUESTIONS.

1. *What does the term "metallic" mean when used to describe a telephone line?*
2. *Why are "earth-return" lines not generally used for telephone services?*
3. *How are the wires of a telephone circuit usually designated in external plant?*
4. *How would you describe a junction line?*
5. *In what form do subscribers' lines normally leave the exchange?*
6. *List four standard methods used to distribute subscribers telephone lines.*
7. *What is the function of an I.T.P.?*
8. *Describe one pair drop wire.*
9. *What is a "common use" pole?*
10. *What are the advantages of joint use construction?*
11. *What is meant by "open wire"?*
12. *Give two main differences between trunk and subscribers open wire routes.*
13. *What are the three basic parts of subscribers telephone cable?*
14. *What is the difference between "twin" and "quad" cable?*
15. *Briefly describe the make-up of "unit" type cable.*
16. *What is the function of the marker pair or quad?*
17. *On what type of line would a P.I.Q.C. cable be used?*
18. *Briefly describe a single quad carrier cable.*
19. *In a coaxial tube, what constitute the two conductors?*
20. *What is the basic function of cabinets and pillars?*
21. *Name the type and size of terminal unit used in each of the following instances:*
    - *(a) When a 2 pair lead-in cable cannot be extended to the telephone.*
    - *(b) To enable drop wires to be connected to an aerial cable.*
    - *(c) When a 30 pair cable is terminated inside the subscribers premises.*
    - *(d) When a 10 pair cable is terminated on a cable terminal pole carrying six subscribers open wire lines in an area subjected to lightning strikes*
22. *Two country exchanges 20 kilometres apart are connected by a 2.01 mm H.D.C. metallic line. Calculate the "line resistance" of the line.*

END OF PAPER

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